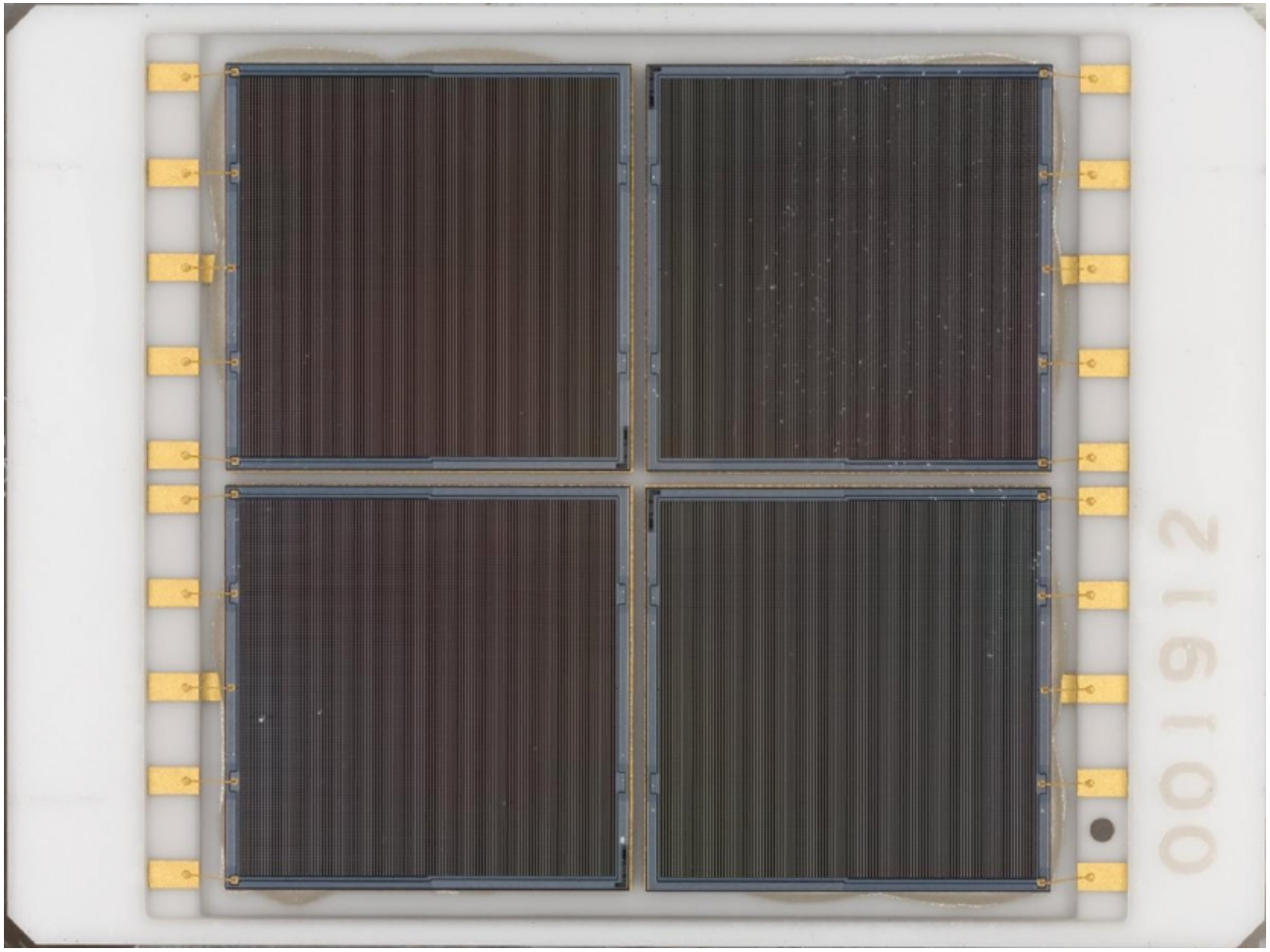
MPPC array measurement.
SiLab/UTFSM
26/09/2013

Outline

- Measurement stations.
- Measurement procedure.
- Results.

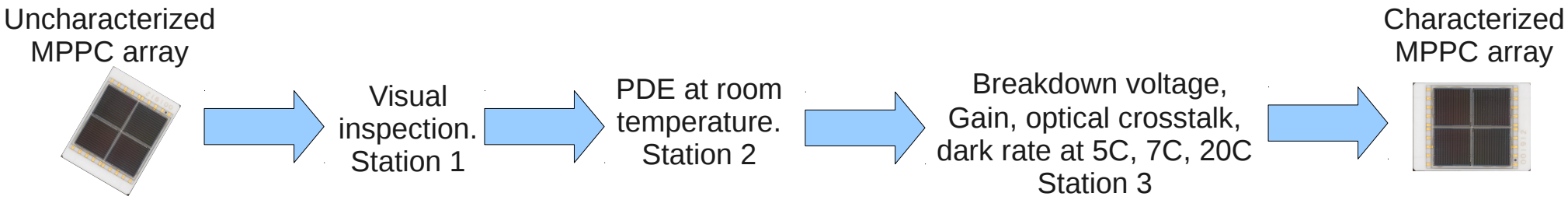
MPPC array



- Model: S12045(X)
- 2X2 array of 2x2
  MPPC array.
  16 individual MPPC cells 3x3 mm.
- Operational voltage around 70 V.
- 3600 pixel 50x50 um per MPPC.

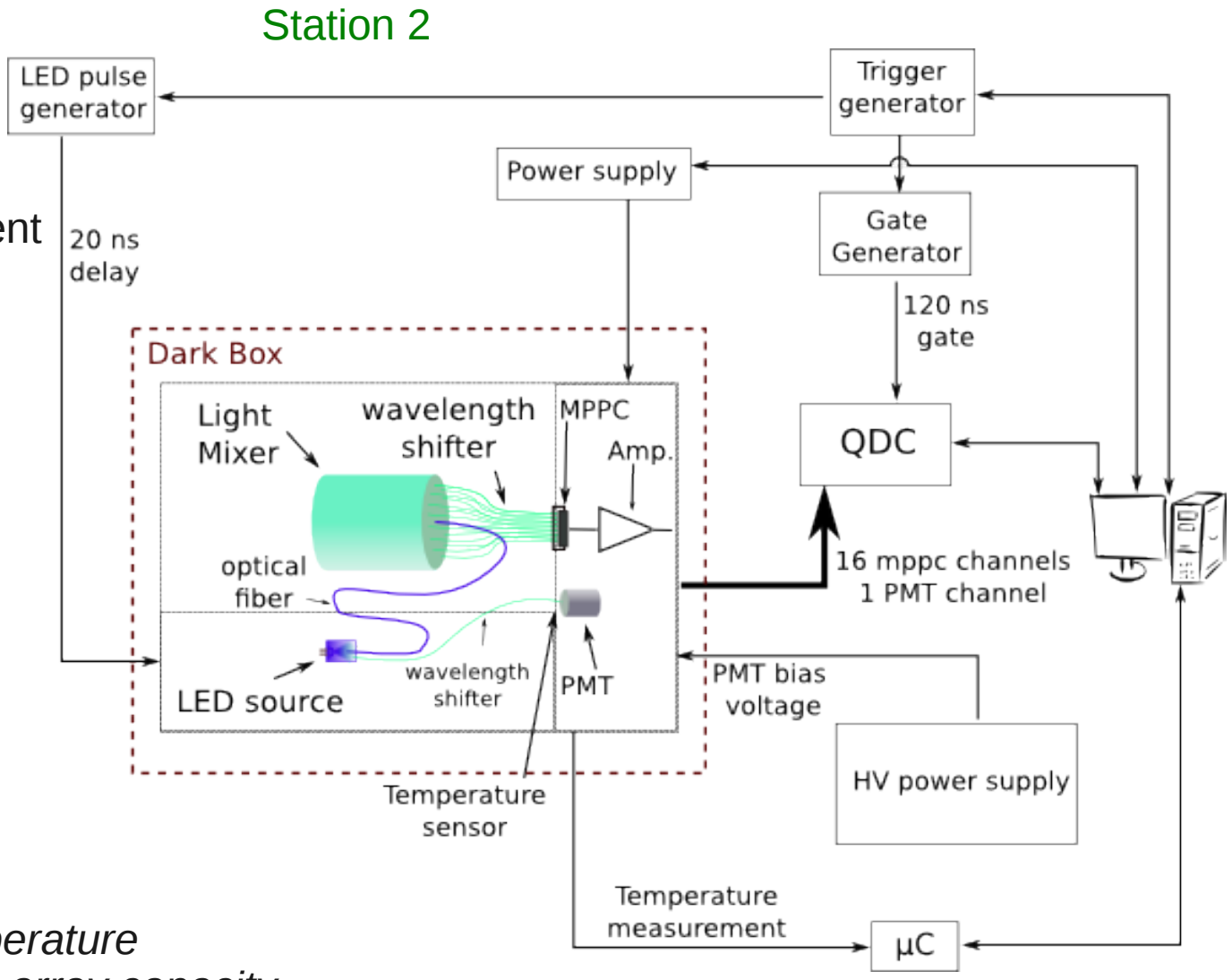
Measurement program

We used three stations to get the complete characterization of the MPPC arrays



Measurement stations (1)

- PDE measurement

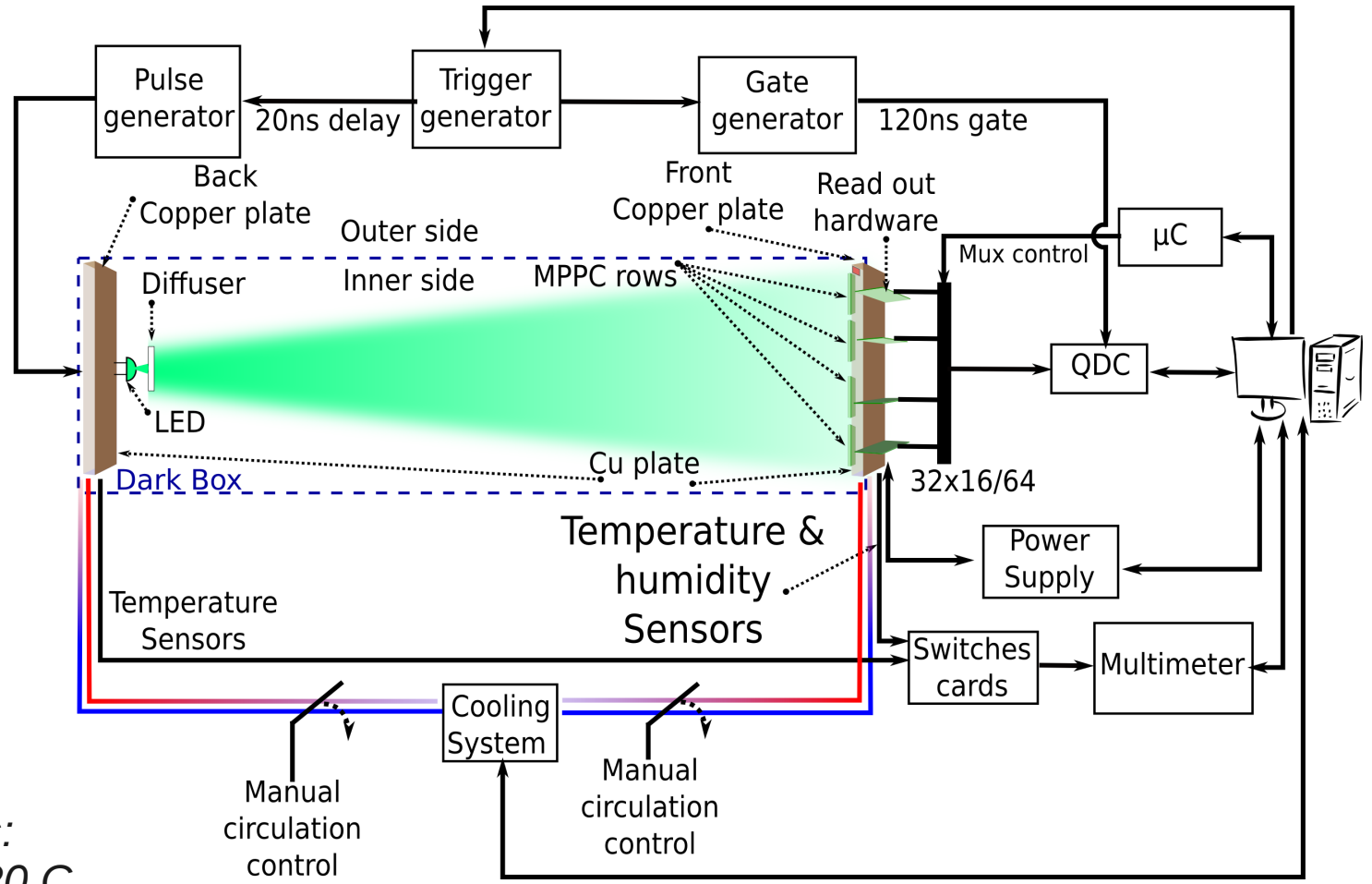


- *Room temperature*
- *One MPPC array capacity*

Measurement stations (2)

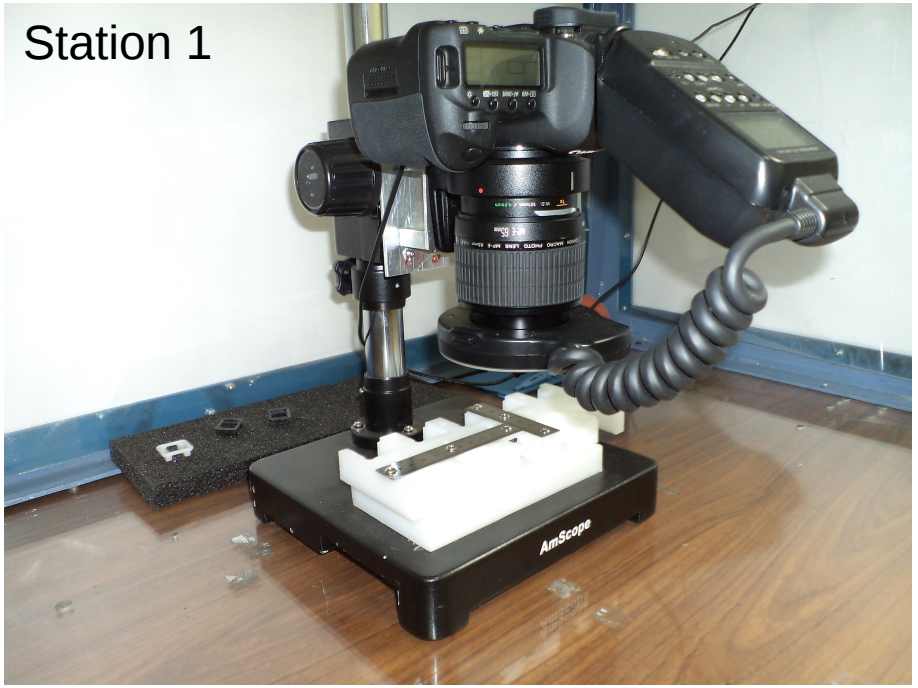
- Breakdown voltage
- Gain
- Optical crosstalk
- Dark rate

Station 3

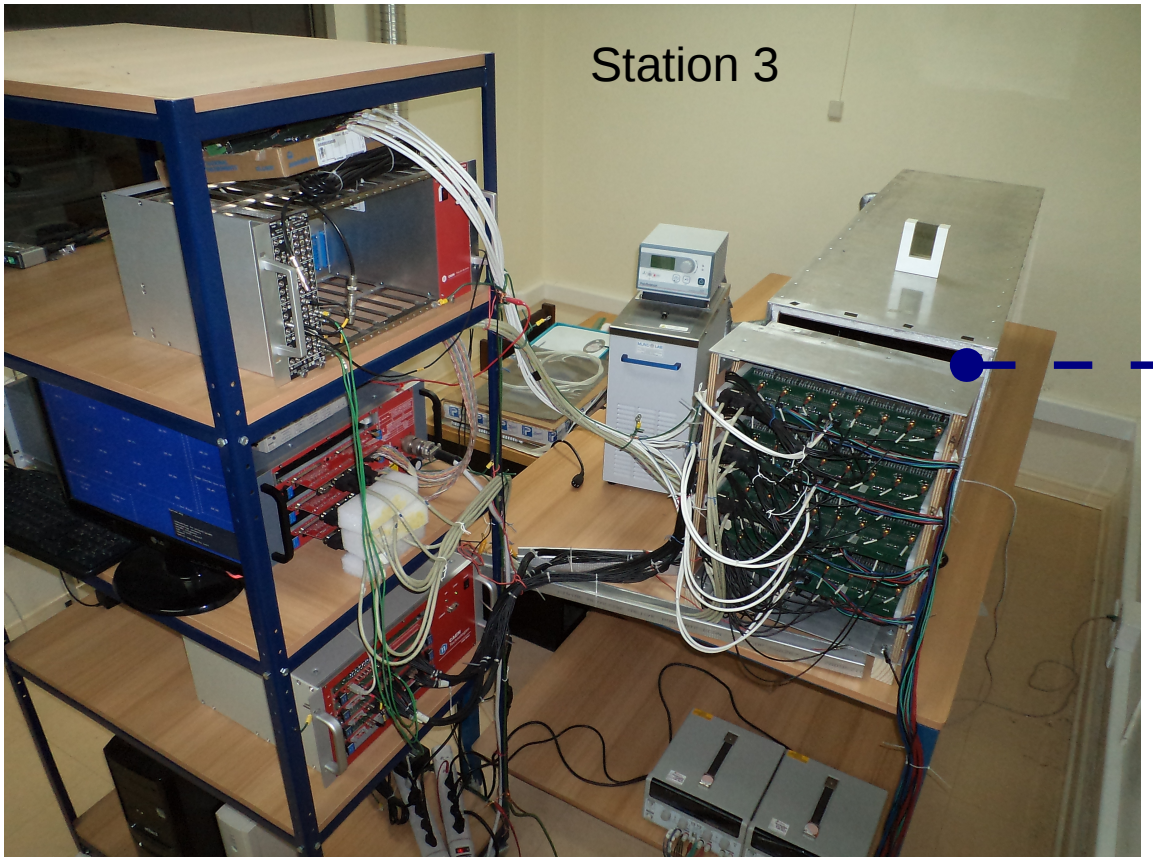


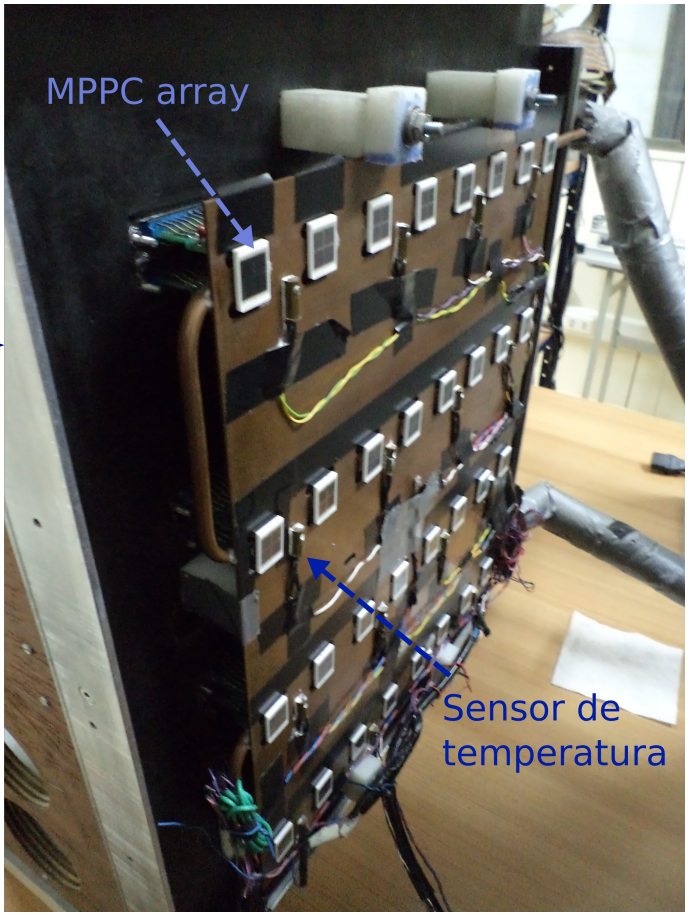
- *Temperatures: 5 C,7 C and 20 C*
- *32 MPPC array capacity*

Measurement stations (3)



Measurement stations (4)





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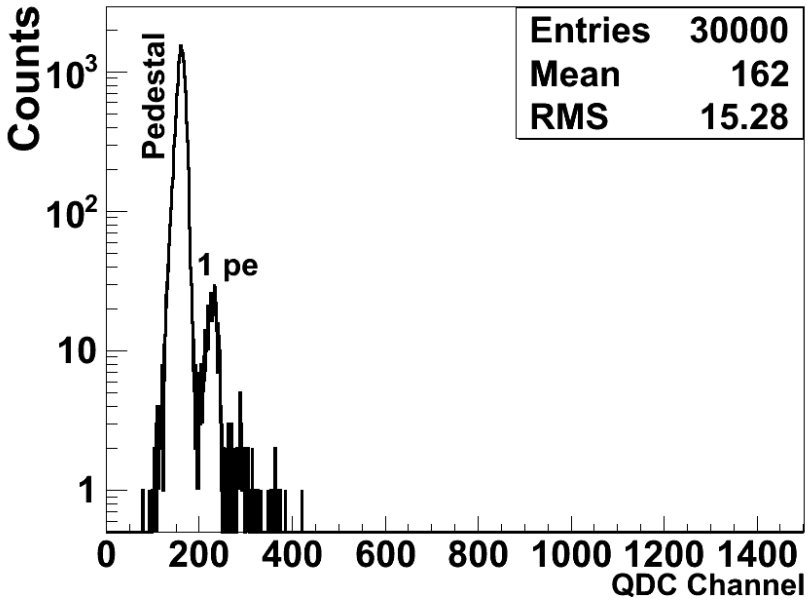
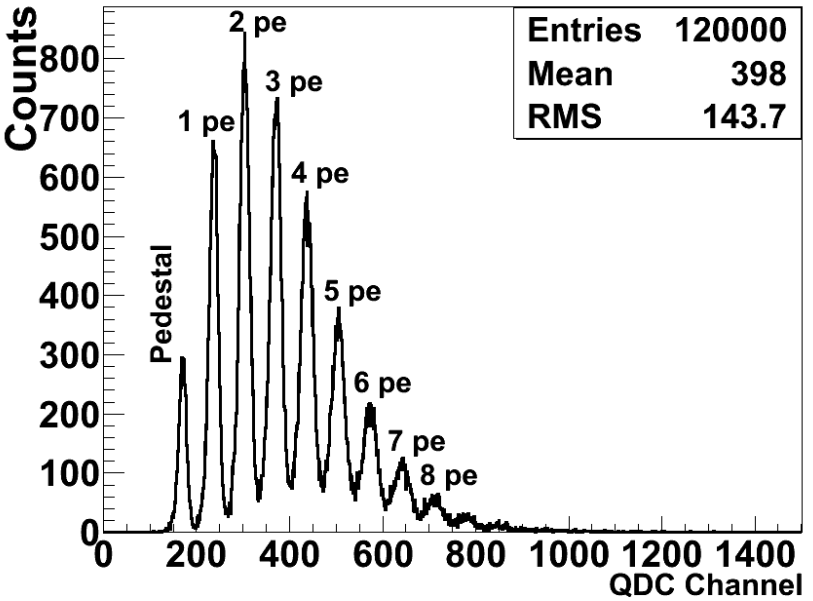
Measurement procedure

Given a temperature T_{USM}, for each cell in one MPPC array we have histograms with and without light at 13 different bias voltages[1] V_i, starting with corrected Hamamatsu operational voltage[2], decreasing -0,1 V steps.





[1] $V_i = V_0 - 0{,}1 \cdot i$

[2] *temperature correction*:
$\Delta t \cdot 0.056[V] \Rightarrow V_0 = \bar{V}_{hammamatsu} + (25 - T_{usm}) \cdot 0.056$

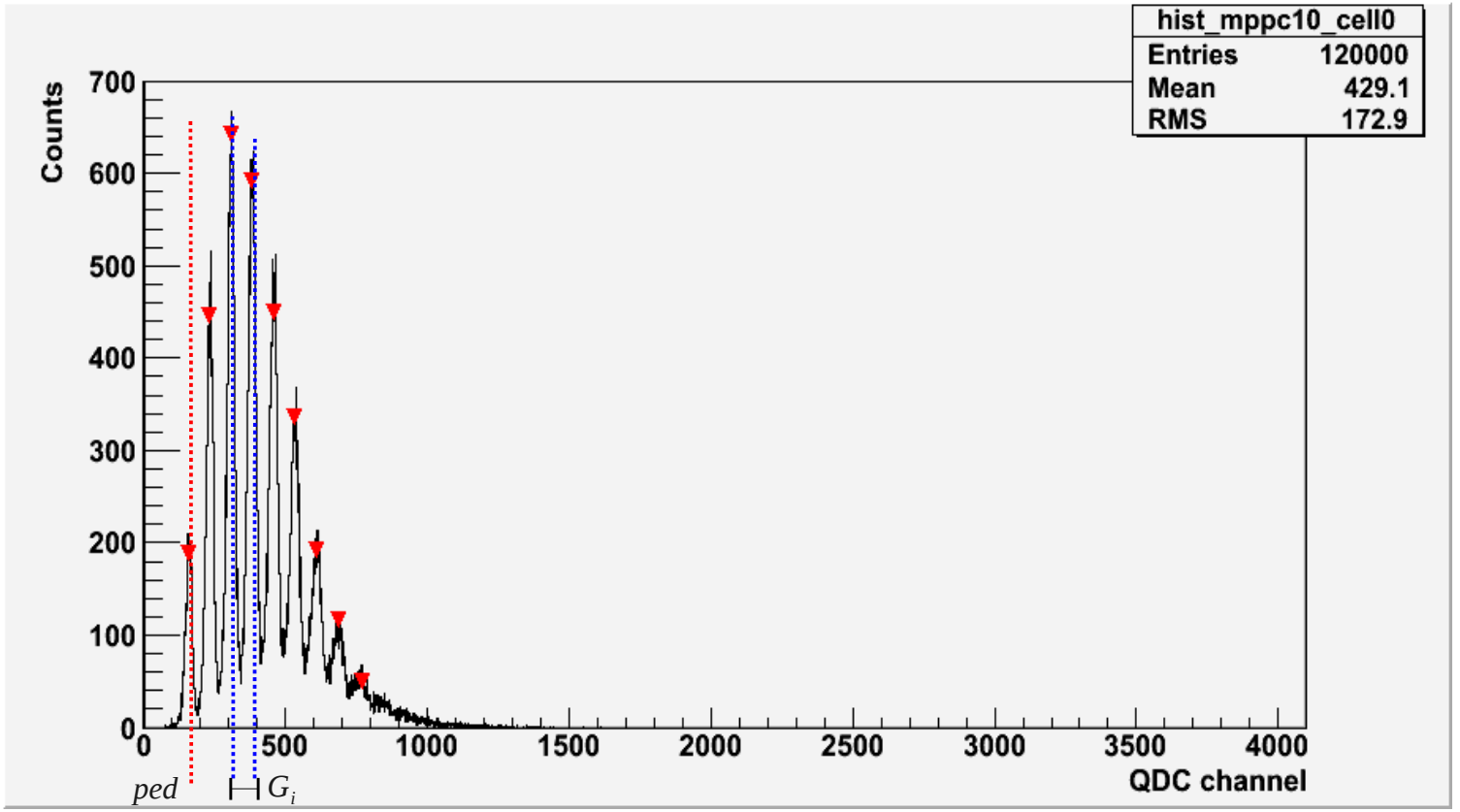
From these histograms we get gain (G_i), average number of photoelectrons (<*N*>), Optical cross-talk (*OC*) according to:

Mean

RMS

ped

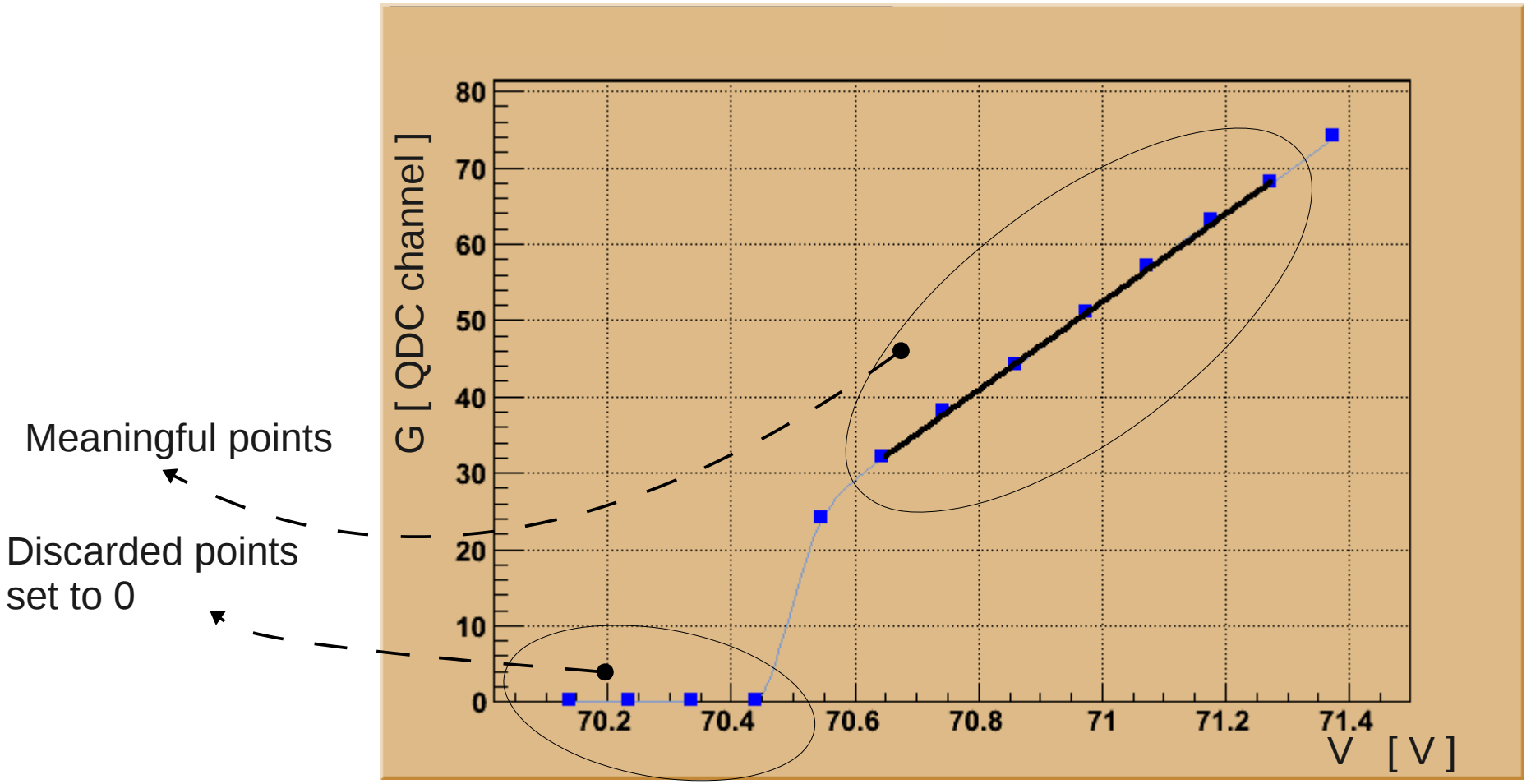
G_i



$$OC = \frac{\sigma^2 - \mu + \sqrt{(\sigma^2 - \mu)^2 + 4\mu^2}}{2\mu} - 1 \qquad (1)$$

$$\langle N \rangle = \frac{-(\sigma^2 - \mu) + \sqrt{(\sigma^2 - \mu)^2 + 4\mu^2}}{2} \qquad (2)$$

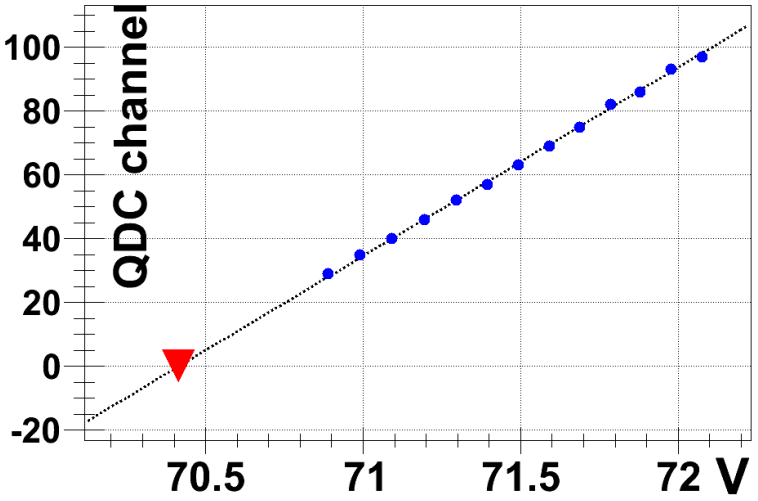
For each channel we estimate Break Down Voltage from first order polynomial fit over the meaningful voltages.

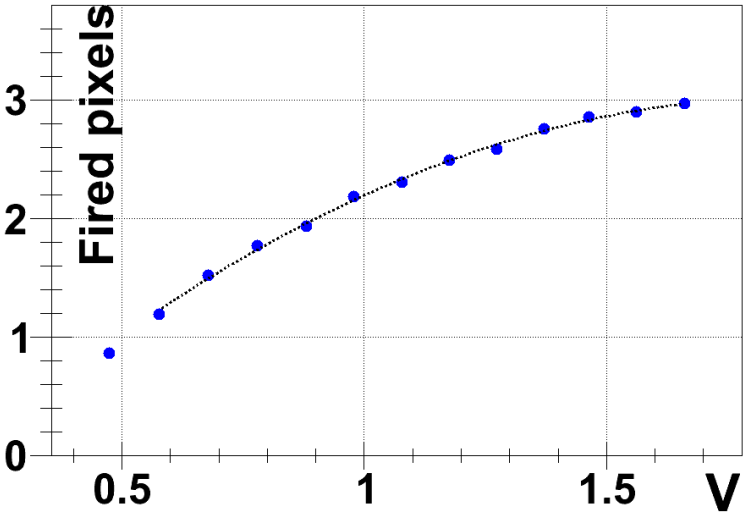


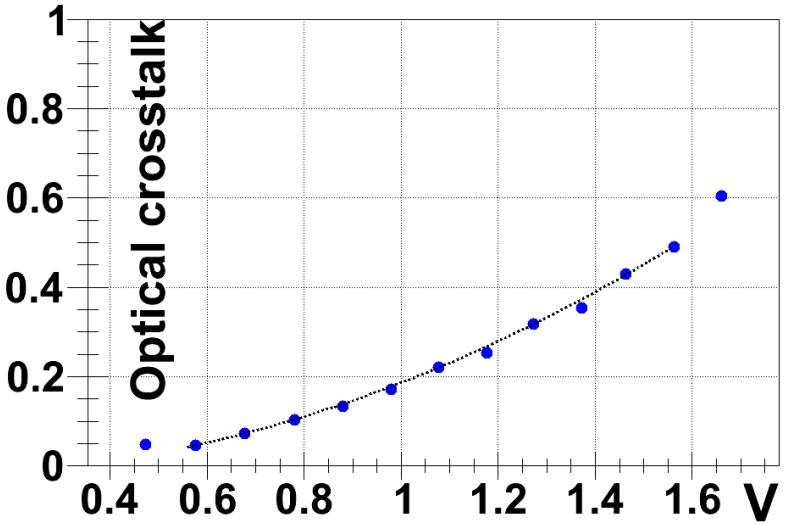
$$G(V) = p_0 + p_1 \cdot V$$

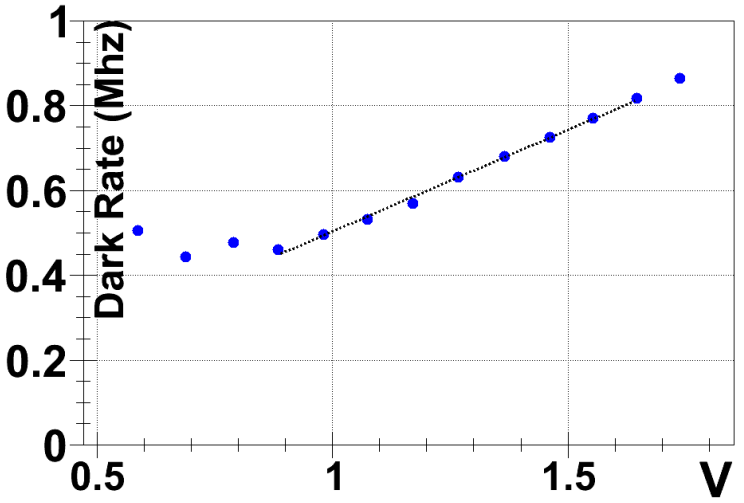
$$G(V_{BDV}) = 0 \quad \Rightarrow \quad V_{BDV} = -p_0 / p_1$$

Results for one MPPC channel



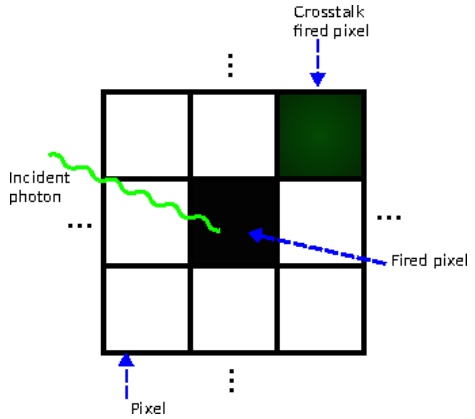






Optical crosstalk extraction

- We start with a probabilistic model.
- We write expressions for mean and variance of this model.
- Using the mean and variance we extract the mean number of photoelectrons and the optical crosstalk.



$$P_{xt}(k|1) = \binom{N_n}{k} p_{xt}^k (1-p_{xt})^{N_n - k}$$

$$P_{xt}(k = k_1 + \cdots k_i | i) = \sum_{j=1}^{i} \binom{N_n}{k_i} p_{xt}^{k_i} (1-p_{xt})^{N_n - k_i}$$

$$= \binom{N_n i}{k} p_{xt}^k (1-p_{xt})^{N_n i - k}$$

$$P_{xt}(k|i) = \frac{(iOC)^k e^{-(iOC)}}{k!}$$

$$P(n) = \sum_{k=0}^{n} \frac{\langle N \rangle^k e^{-\langle N \rangle}}{k!} \times \frac{(k \times OC)^{n-k} e^{-k \times OC}}{(n-k)!}$$

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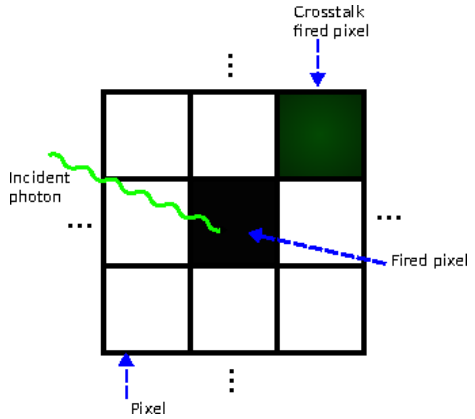

$$P(n) = \sum_{k=0}^{n} \frac{\langle N \rangle^k e^{-\langle N \rangle}}{k!} \times \frac{(k \times OC)^{n-k} e^{-k \times OC}}{(n-k)!}$$

$$G(z) = E[Z^X] = \sum_{j=0}^{\infty} p_j z^j$$

$$\mu = G'(1)$$
$$\sigma^2 = G''(1) - G'(1)^2 + G'(1)$$
$$\mu = \langle N \rangle (1 + OC)$$
$$\sigma^2 = \langle N \rangle (1 + 3OC + OC^2)$$

$$OC = \frac{\sigma^2 - \mu + \sqrt{(\sigma^2 - \mu)^2 + 4\mu^2}}{2\mu} - 1 \qquad (1)$$

$$\langle N \rangle = \frac{-(\sigma^2 - \mu) + \sqrt{(\sigma^2 - \mu)^2 + 4\mu^2}}{2} \qquad (2)$$

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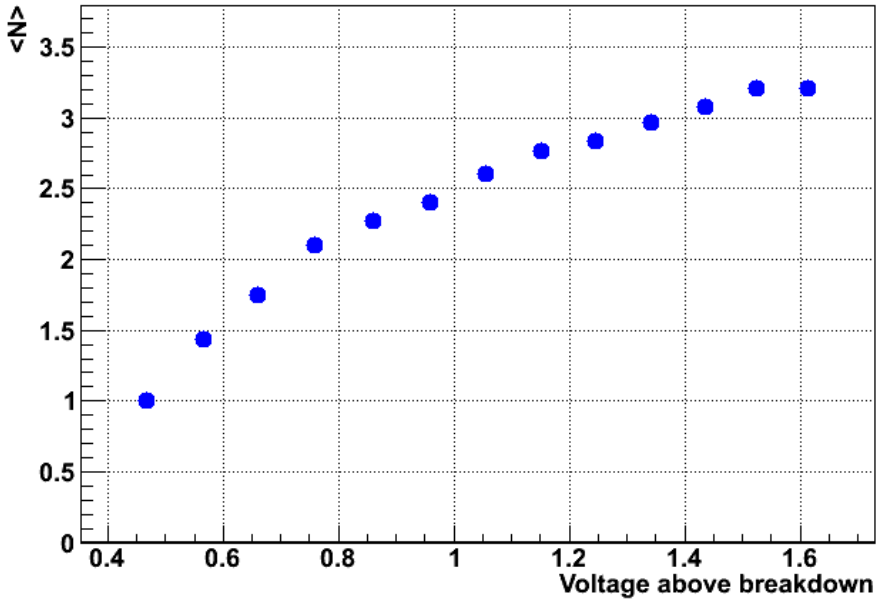
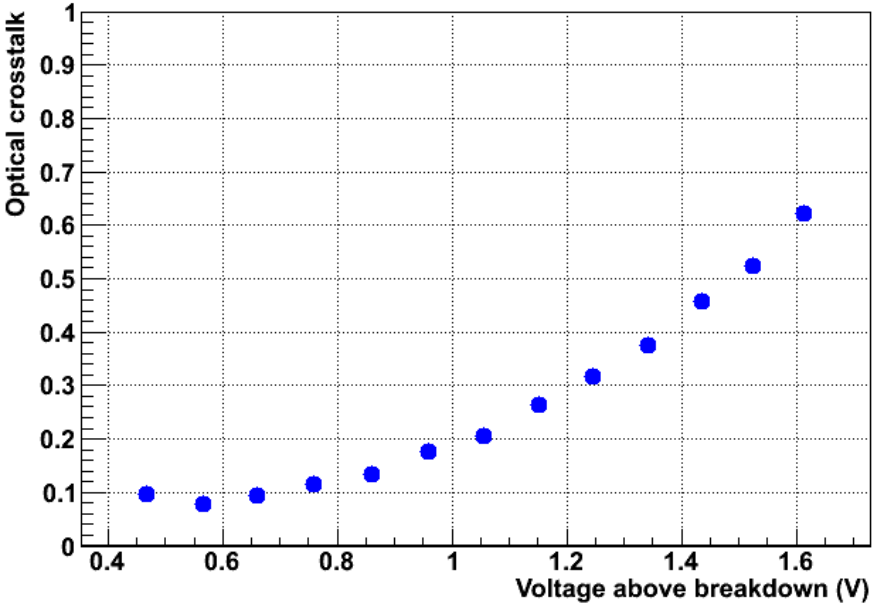




PDE extraction (station 3)

- Calibration using 400 MPPC array.
- Using some MPPC array with known PDE from station 2, we estimate the PDE in station 3.

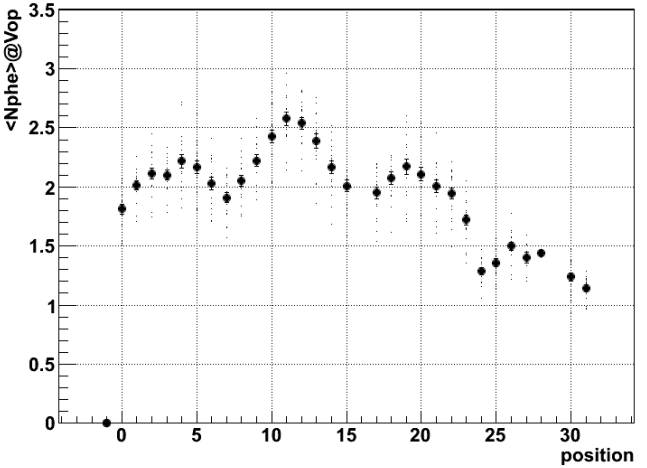
$$n_{phe}(pos) = PDE(pos) \times LUT_T(pos) \times C$$

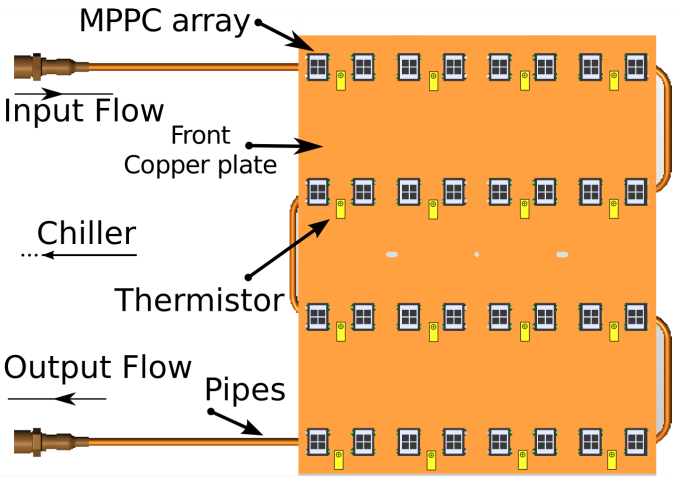
$$A_{phe}(pos) = LUT_T(pos) \times C$$

$$\hat{C} = \frac{1}{|P|} \sum_{pos \in P} \frac{n_{phe}(pos)}{LUT_T(pos) \times PDE(pos)}$$

$$\hat{A}_{phe}(pos) = LUT_T(pos) \times \hat{C}$$

$$PDE(pos) = \frac{n_{phe}(pos)}{\hat{A}_{phe}(pos)}$$





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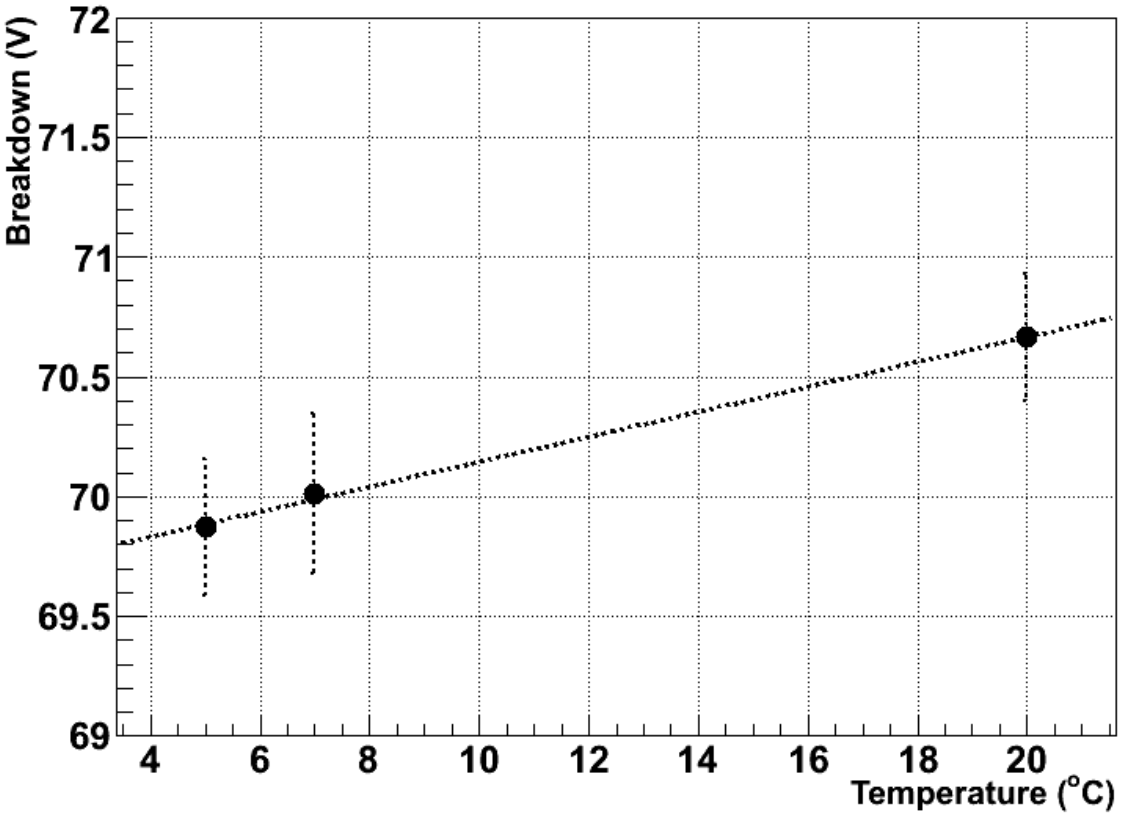
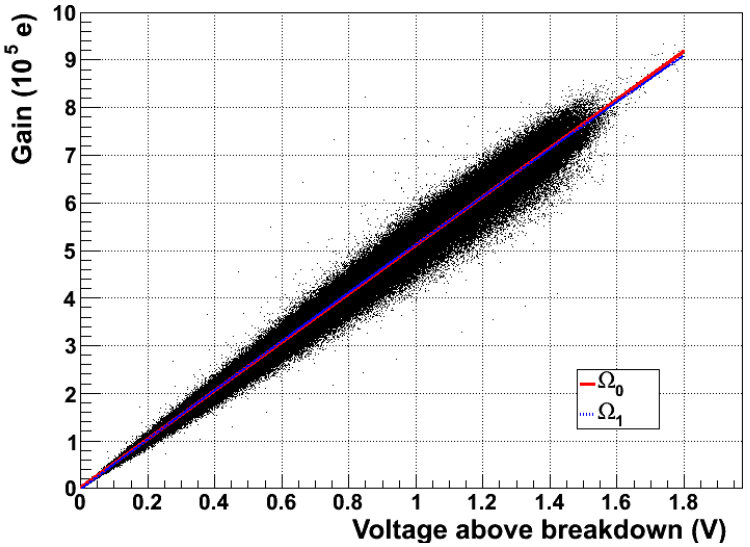
Breakdown voltage

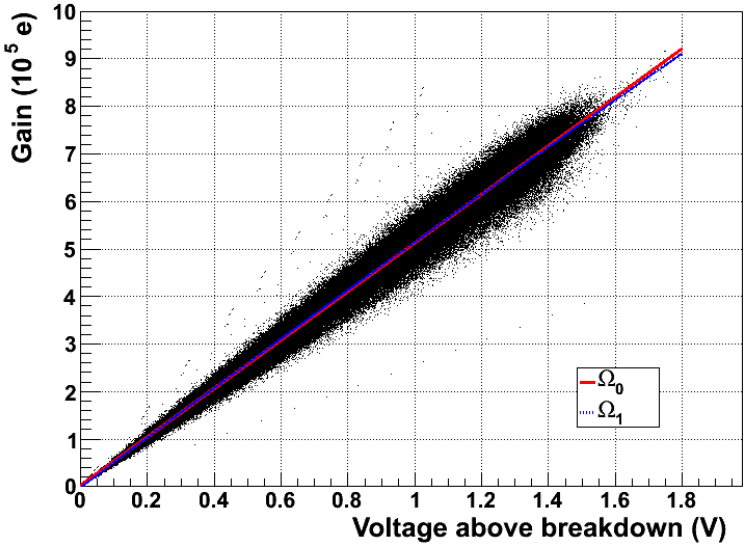


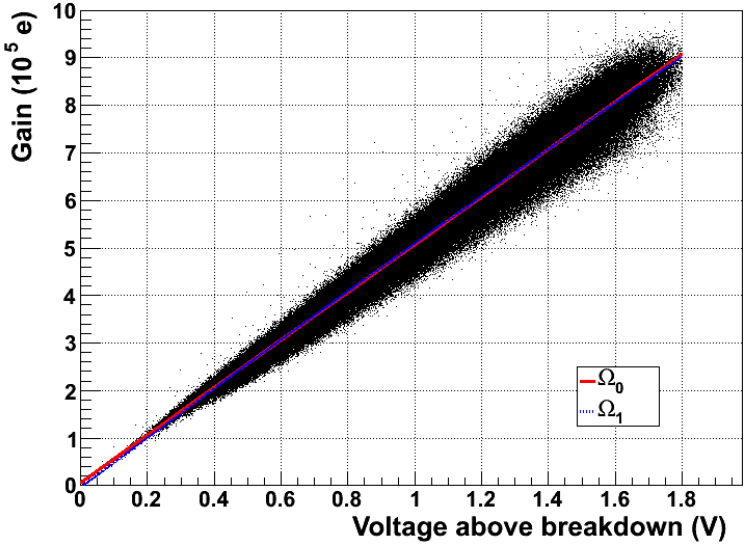
Gain

5C



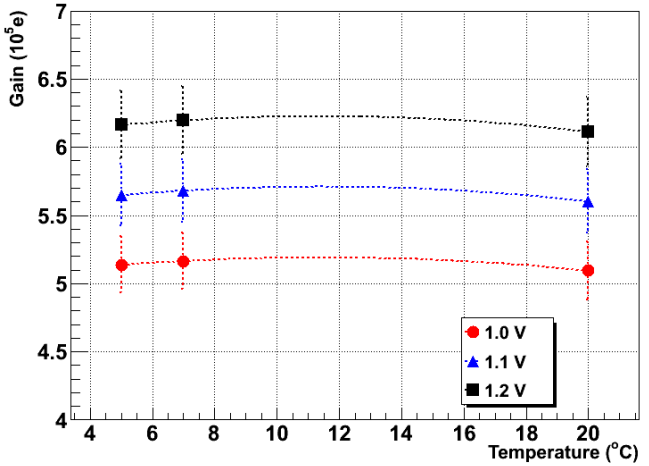
7C





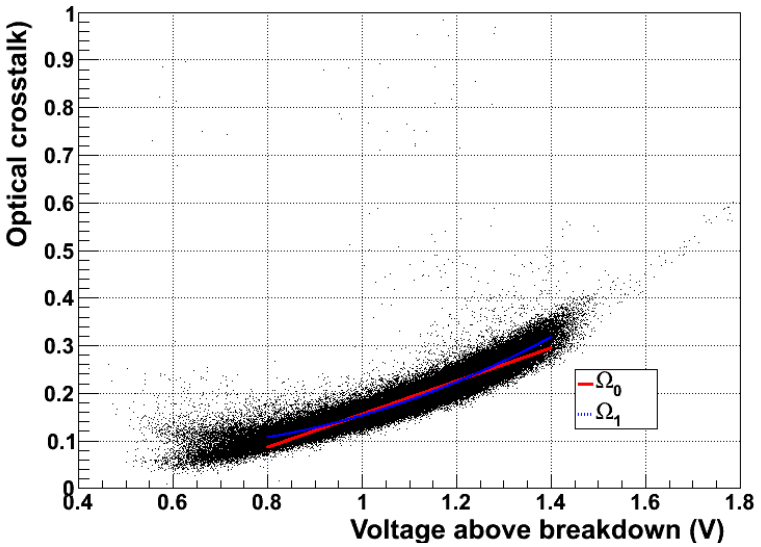
20C

$$G_5 = 5.09\Delta V$$
$$G_7 = 5.11\Delta V$$
$$G_{20} = 5.01\Delta V$$

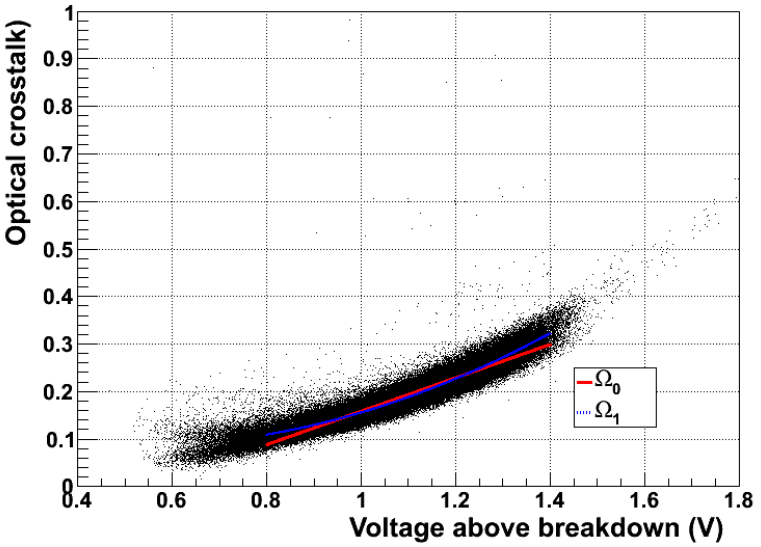


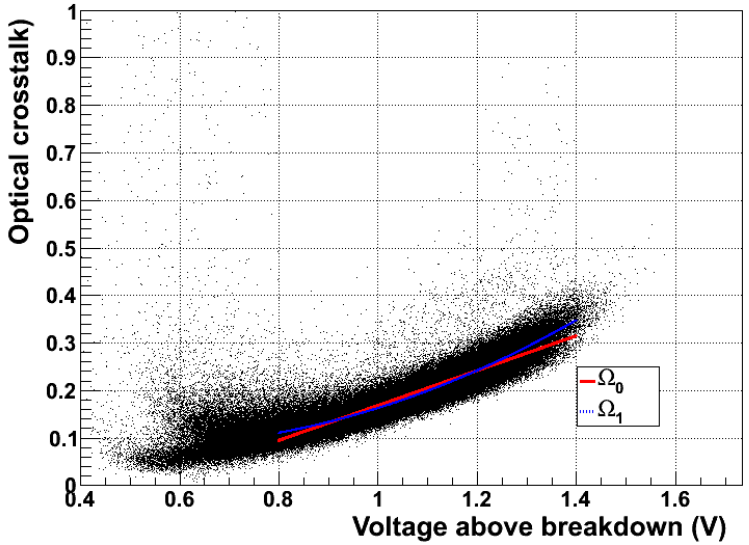
Crosstalk

5C



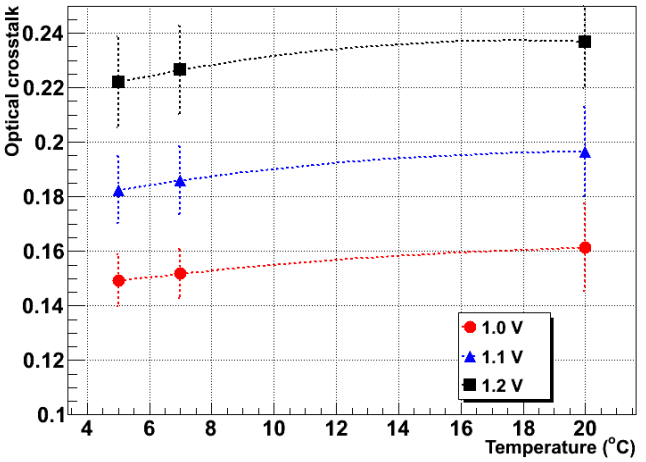
7C





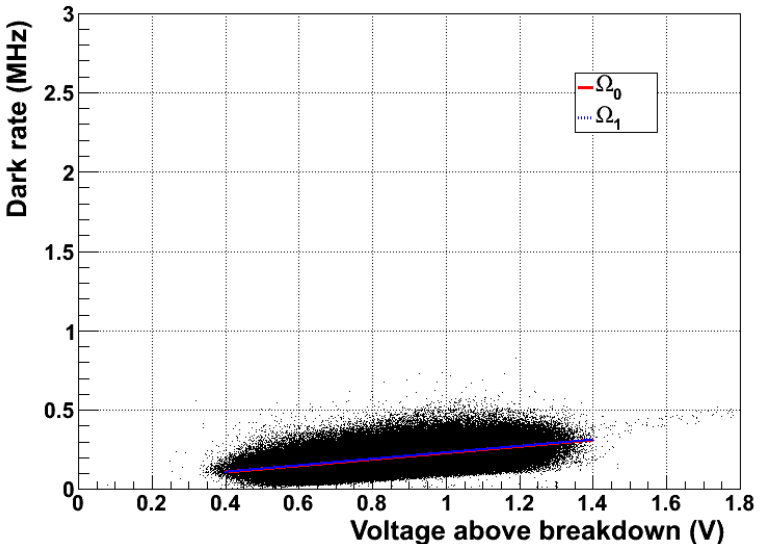
20C

$$XT_5 = 0.302\Delta V^2 - 0.312\Delta V + 0.164$$
$$XT_7 = 0.307\Delta V^2 - 0.319\Delta V + 0.167$$
$$XT_{20} = 0.338\Delta V^2 - 0.347\Delta V + 0.172$$

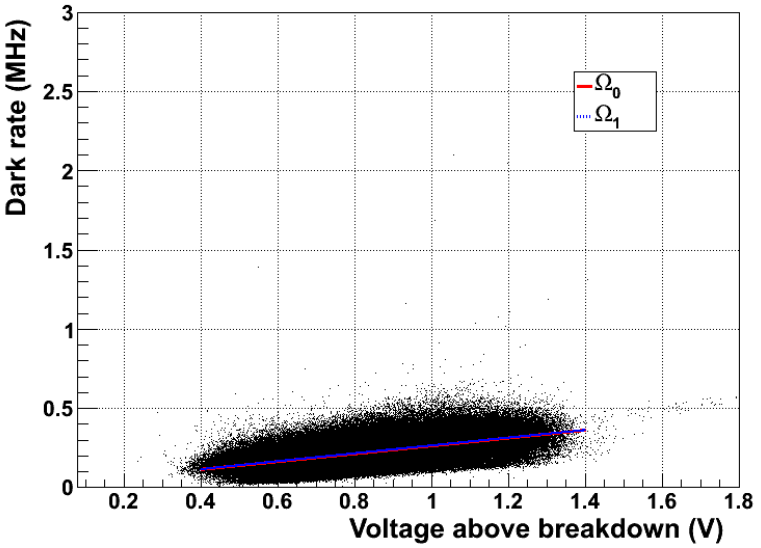


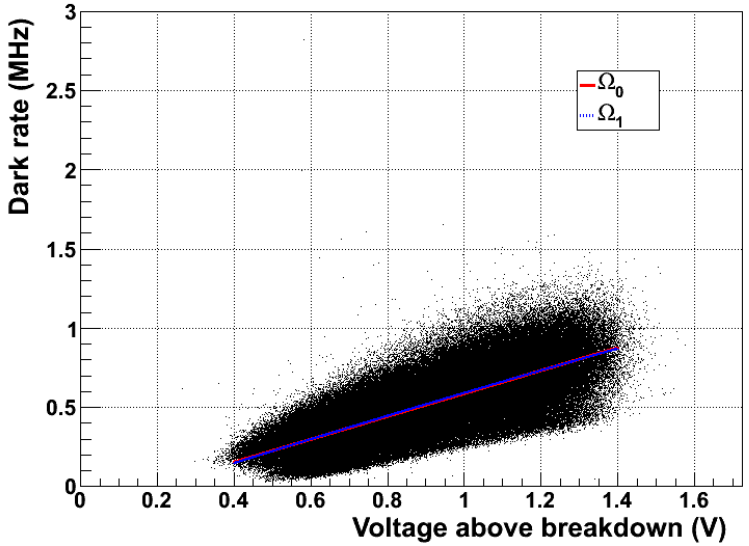
Dark rate

5C



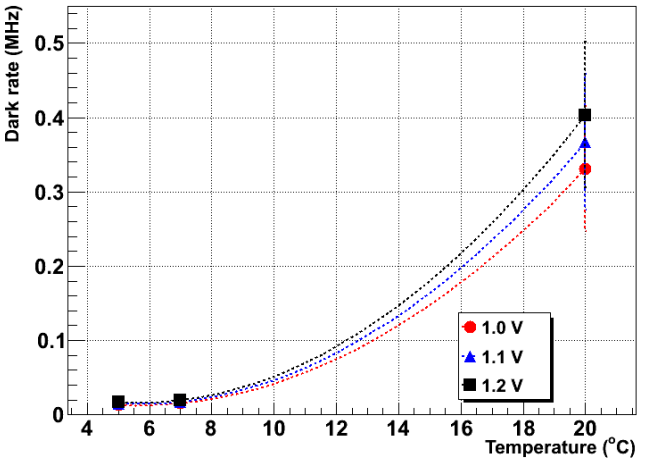
7C





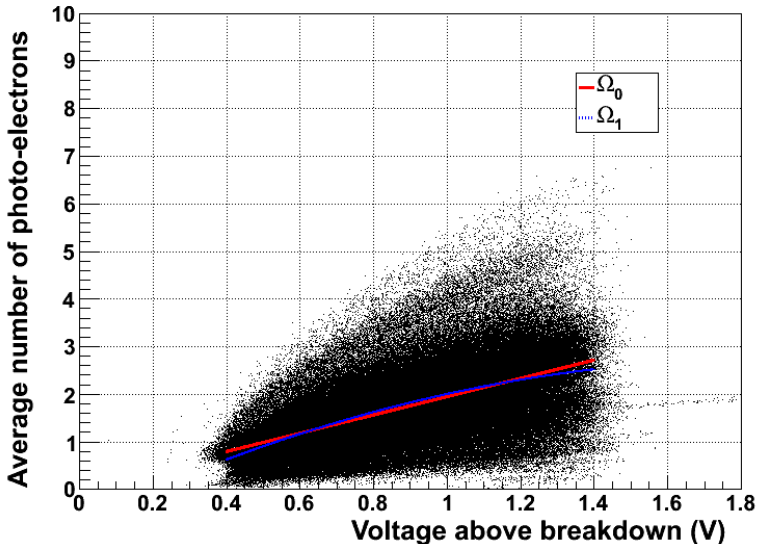
20C

$$DR_5 = 0.203\Delta V + 0.0285$$
$$DR_7 = 0.248\Delta V + 0.0157$$
$$DR_{20} = 0.723\Delta V - 0.135$$

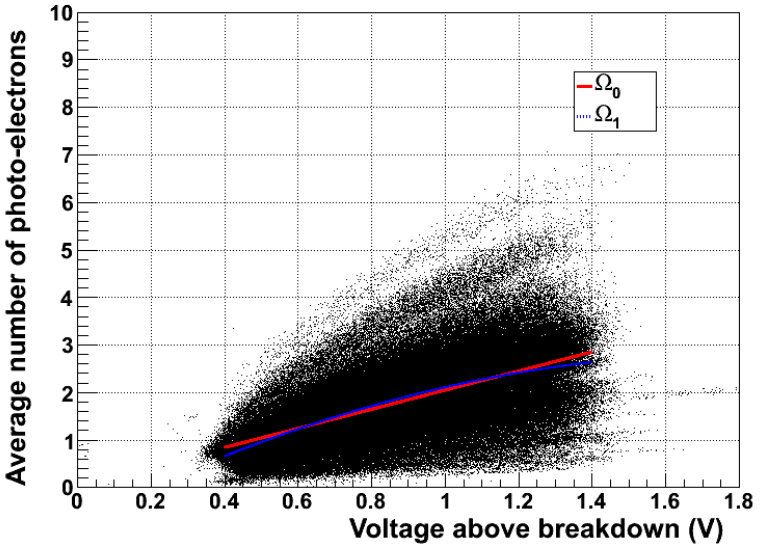


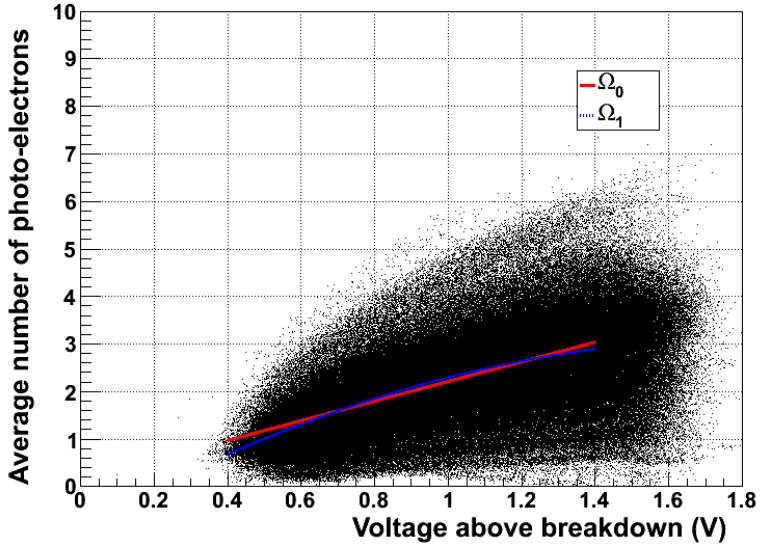
Mean number of photoelectrons

5C



7C

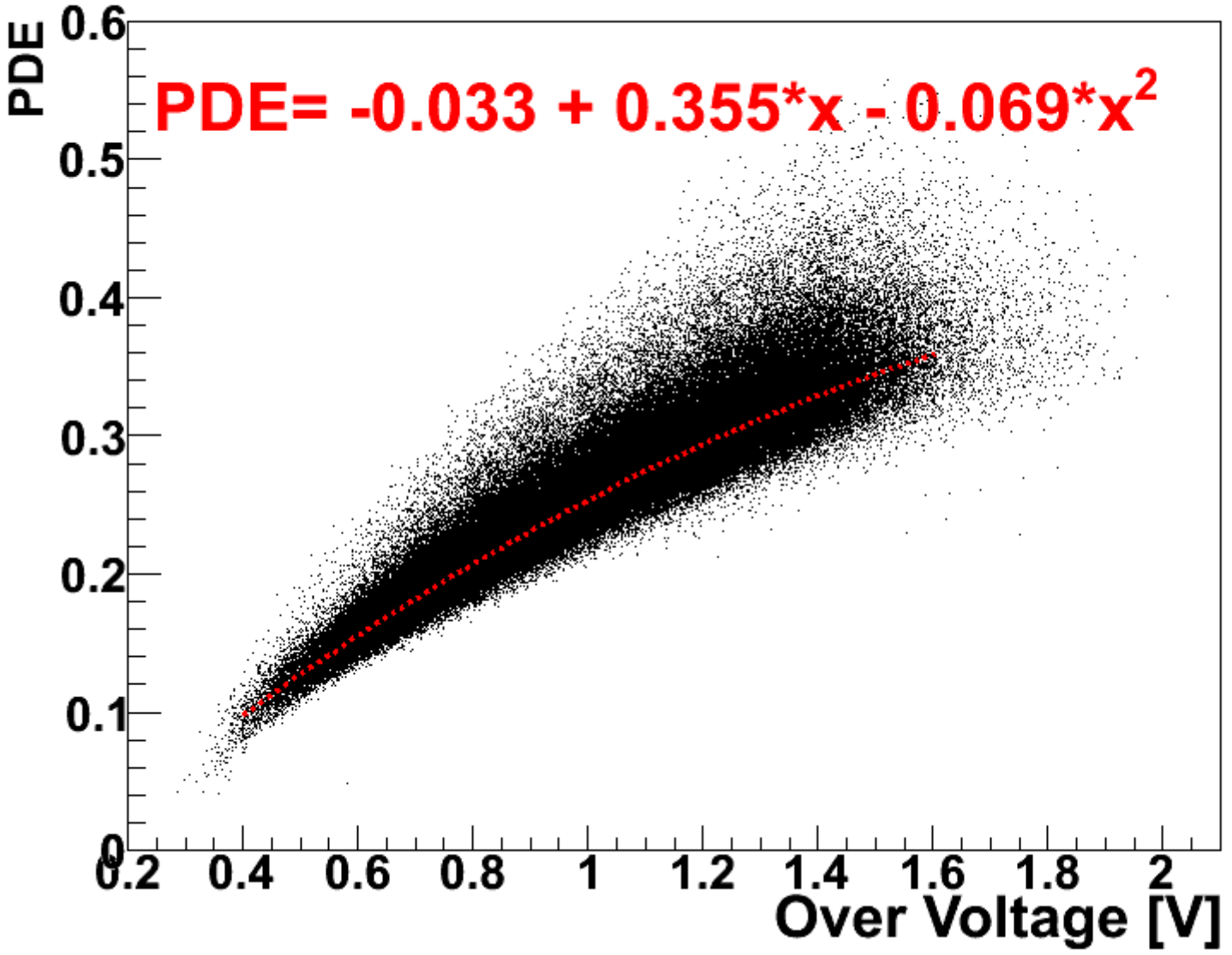




20C

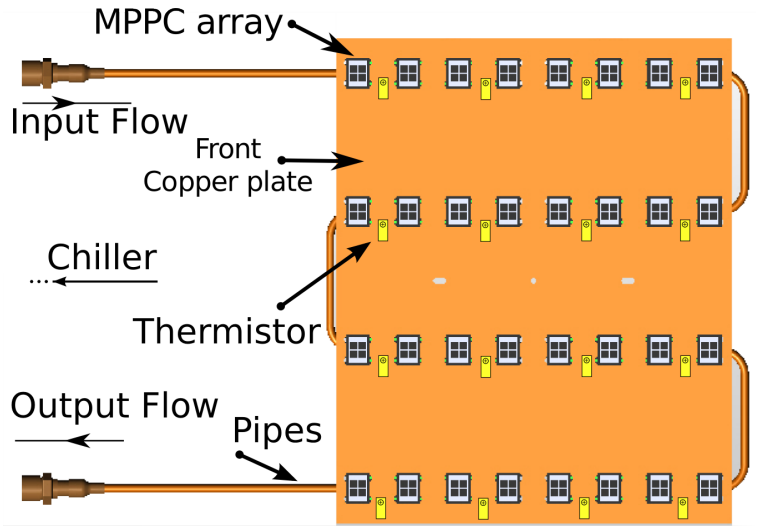
$$\langle N \rangle_5 = -1.00\Delta V^2 + 3.69\Delta V - 0.69$$
$$\langle N \rangle_7 = -1.09\Delta V^2 + 3.95\Delta V - 0.75$$
$$\langle N \rangle_{20} = -1.18\Delta V^2 + 4.34\Delta V - 0.87$$

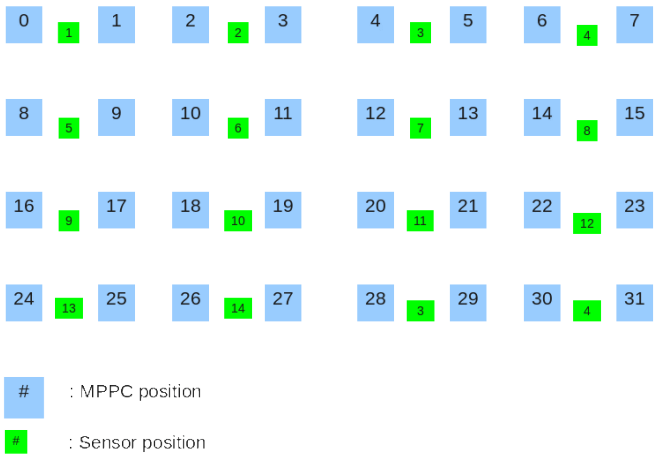
PDE

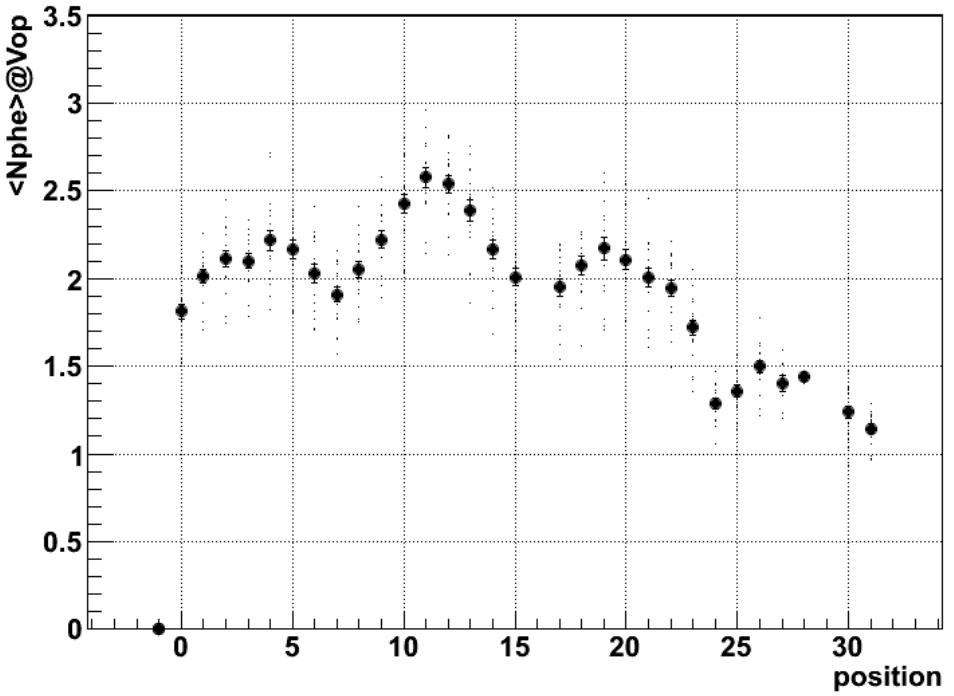

PDE= -0.033 + 0.355*x - 0.069*x^2
PDE
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Over Voltage [V]

BACKUP SLIDES

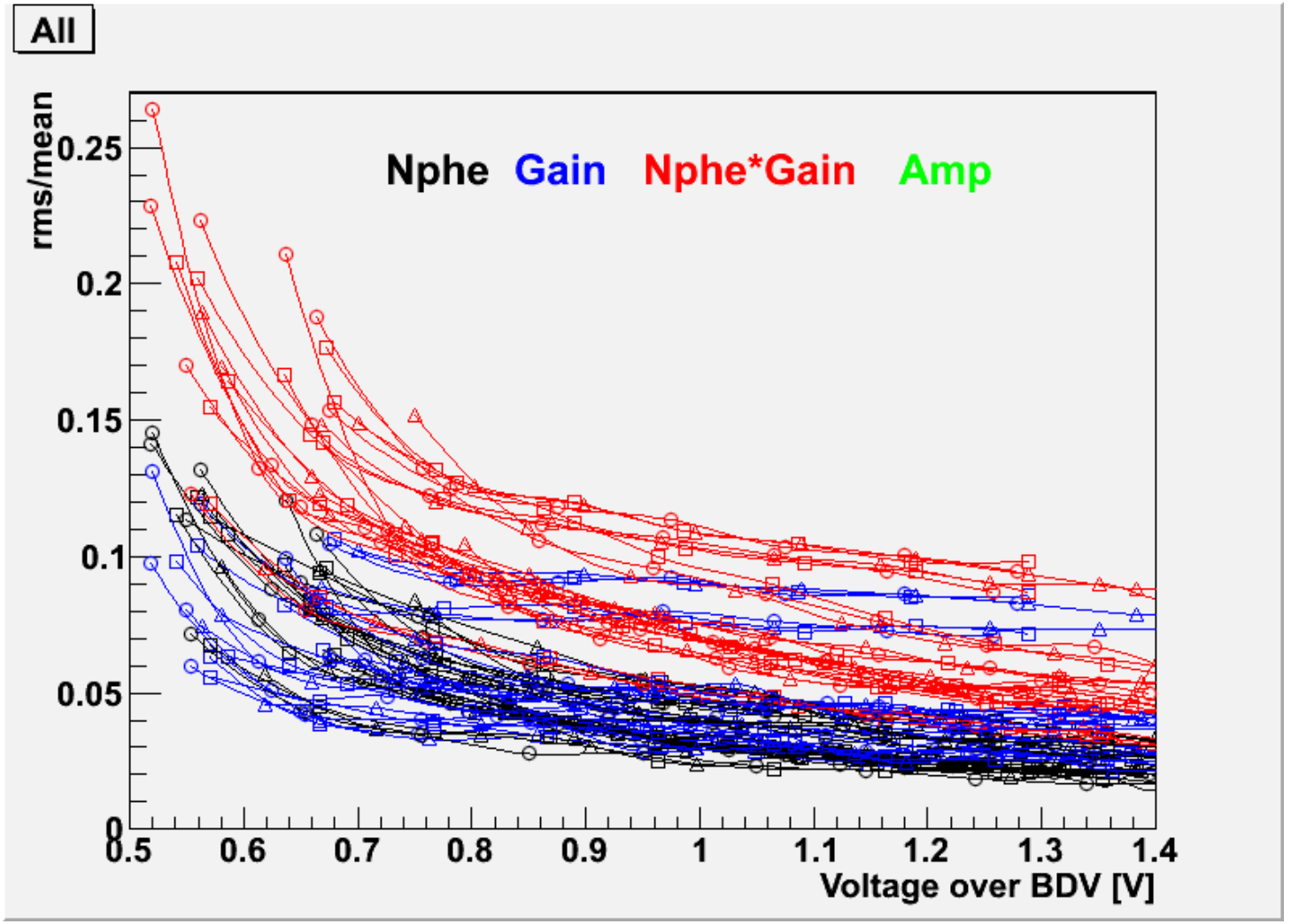
Light distribution across Cu plate



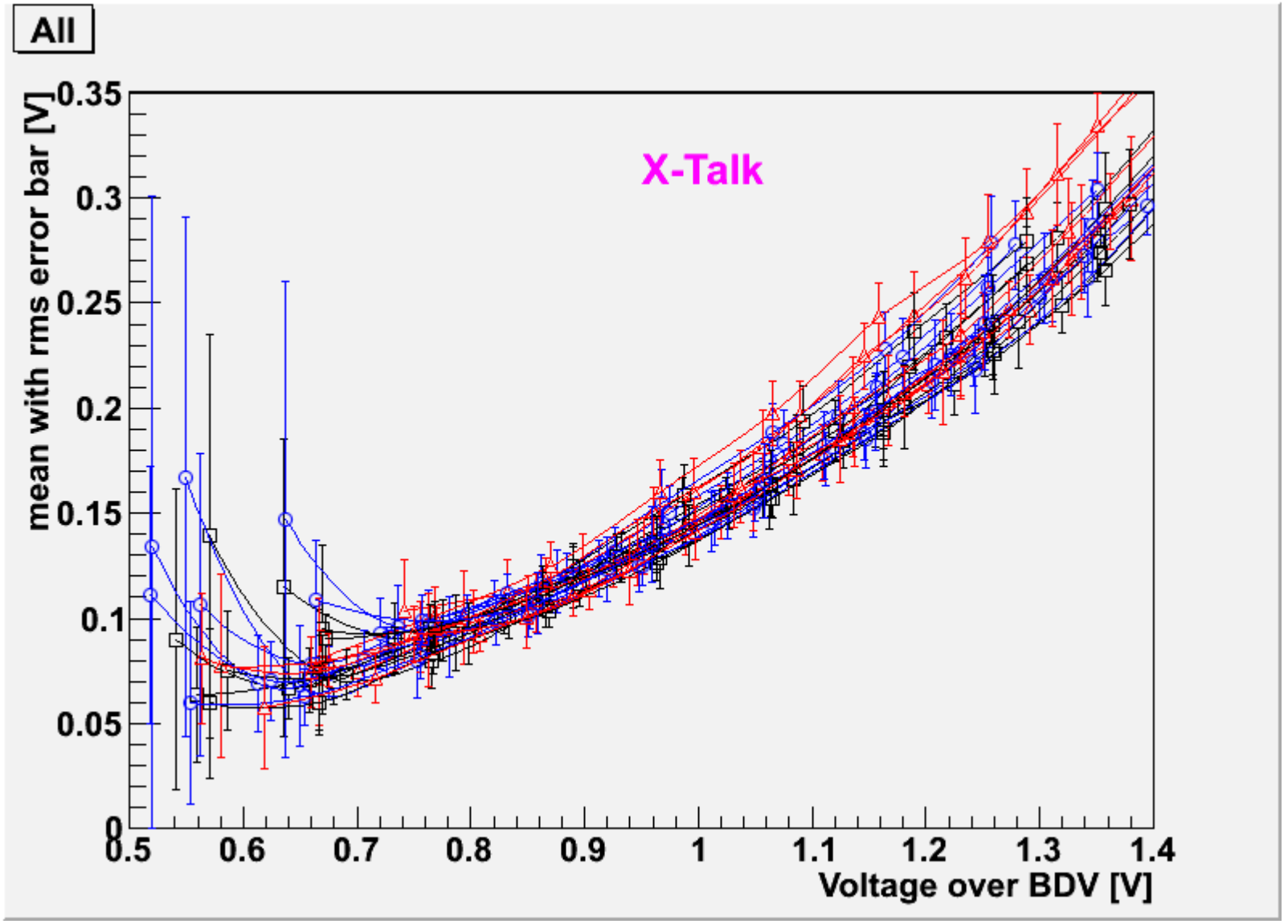




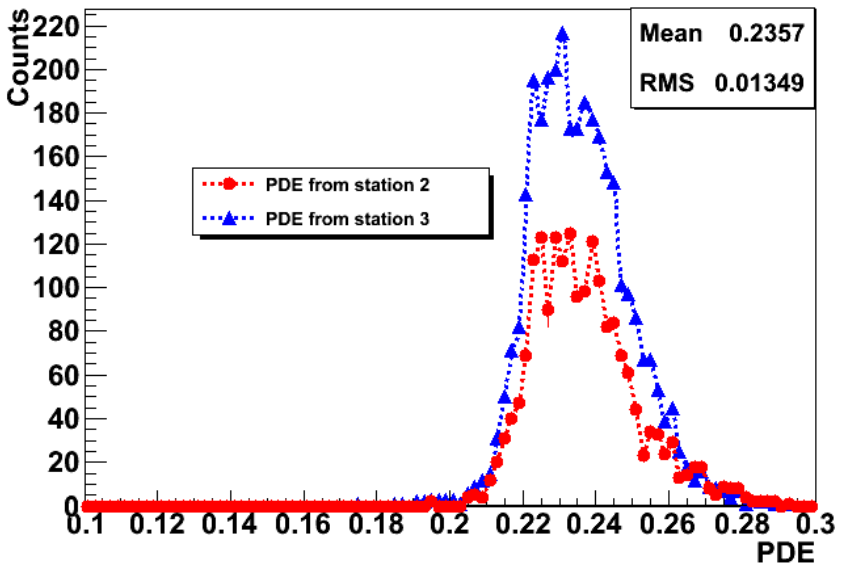
Dispersion

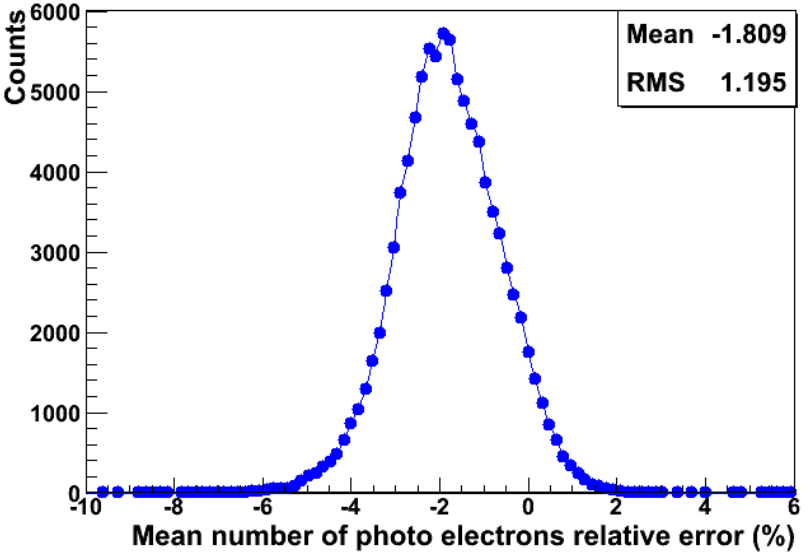

All
rms/mean
0.25
0.2
0.15
0.1
0.05
0
Nphe
Gain
Nphe*Gain
Amp
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

Optical crosstalk temperature dependence



PDE and mean number of photoelectrons validation





$$err = \frac{\langle N \rangle_{or} - \langle N \rangle_{ped}}{\langle N \rangle_{ped}} \times 100$$

$$\langle N \rangle_{ped} = -ln(Prob(0))$$

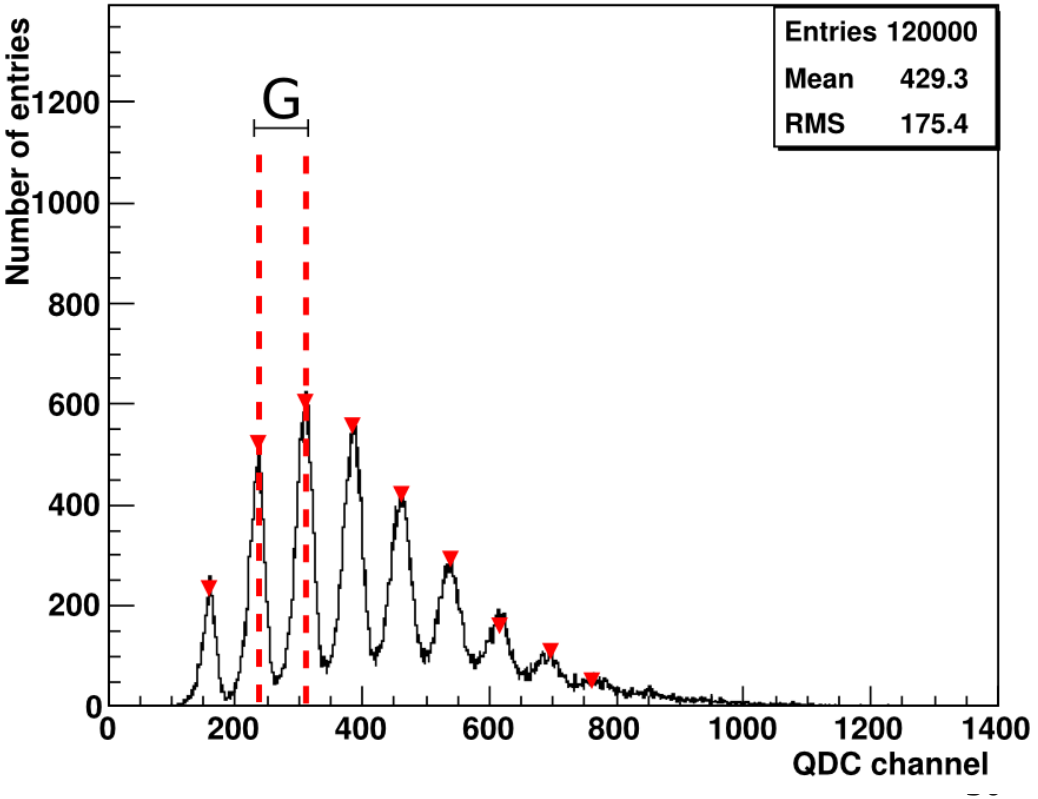
Fuente: G. Bondarenko, NIM A 442 187-192

Extracción de la ganancia

- Se identifican los peaks (TSpectrum).
- Se extrae de la diferencia entre dos peaks vecinos

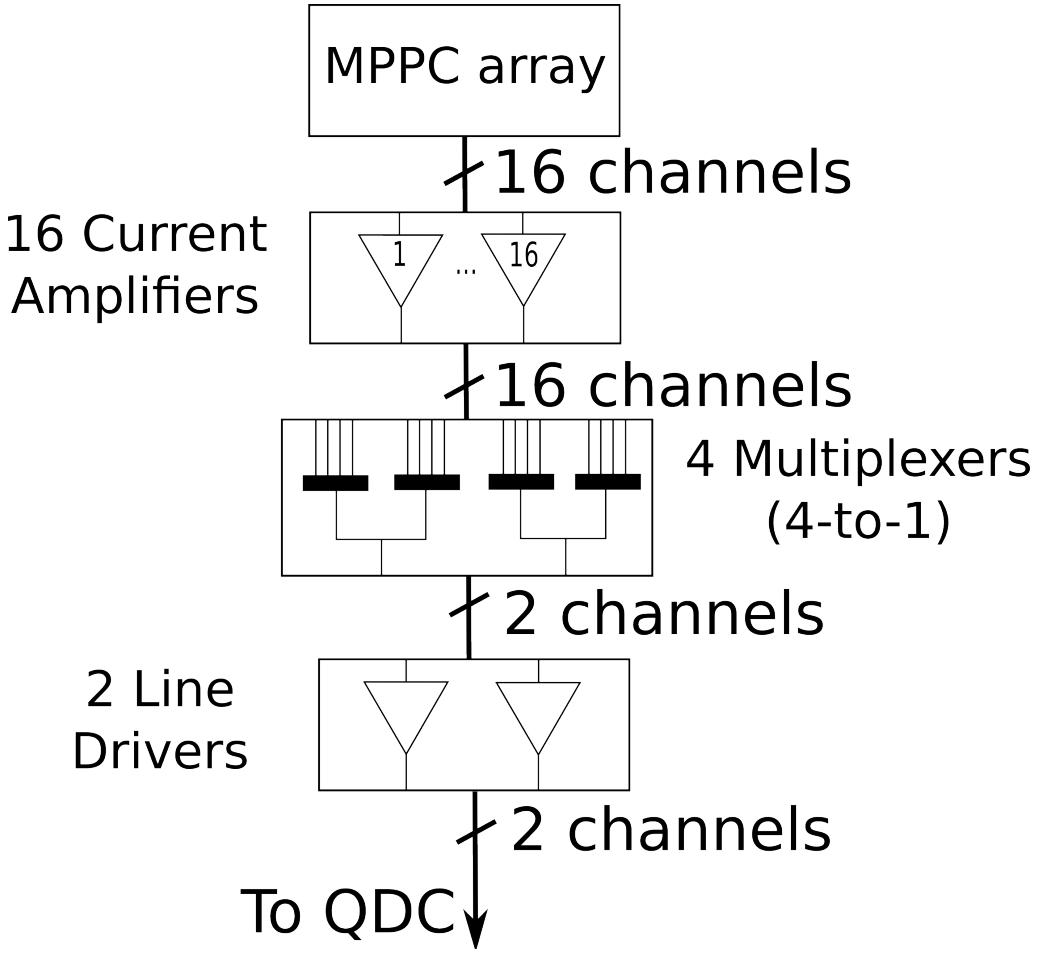
$$N(x) = Gauss(x) + B + Cx$$

$$G_e = \frac{G_{ch} \times QDC_{res}}{e}$$



Fuente: M.A, Mariscotti, NIM A 50(2) 309-320

Readout


MPPC array
16 channels
16 Current
Amplifiers
1
...
16
16 channels
4 Multiplexers
(4-to-1)
2 channels
2 Line
Drivers
2 channels
To QDC